Pacific Northwest National Laboratory

Operated by Battelle for the U.S. Department of Energy

CARPENTER Powder Products

Pacific Northwest National Laboratory
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South Dakota School of Mines and Technology

Development of FUNCTIONALLY GRADED MATERIALS

for Manufacturing Tools and Dies and Industrial Processing Equipment

Project Goal

To develop functionally graded materials for manufacturing tools and dies and process equipment via two new fabrication technologies—**Laser Powder Deposition** (LPD) and **Solid State Powder Forging** (Dynaforge). New materials hybrids and composites will be manufactured into near net shape components that will provide superior performance in terms of tool life, improved part complexity,and reduction in part reject rate.

Benefits

Functionally graded tools and dies will possess **superior elevated-temperature properties**, **improved thermal management**, **dimensional stability**, **wear resistance**, **and resistance to die surface degradation**. The enhanced attributes will lead to reduced scrap and waste in parts manufacturing, reduced cycle times, and increased tooling life.

Industries Targeted

Improved tools and dies fabricated from functionally graded materials will be used in the **aluminum**, **forging**, **glass**, **metal casting**, **and steel** *Industries of the Future*.

Estimated Savings

The anticipated benefits of this project include reducing energy consumption by **120 trillion Btu per year**, and reducing environmental emissions by **over 2.3 million tons of CO_2** and **64,000 tons of other emissions per year**. In addition, by developing and deploying functionally graded tools and dies in the manufacturing industry, an economic benefit of **$4.22 billion/year** to the United States industry can be realized.

GLASS FORMING INDUSTRY	ALUMINUM CASTING INDUSTRY	AUTOMOTIVE FORGING INDUSTRY
Energy savings **7.61 trillion Btu/year**	Energy Savings **104 trillion Btu/year**	Energy Savings **7.88 trillion Btu/year**
Economic savings **$127 million/year**	Economic Savings **$2.88 billion/year**	Economic Savings **$1.21 billion/year**

UNITED STATES
Department of Energy

Office of Science
U.S. DEPARTMENT OF ENERGY

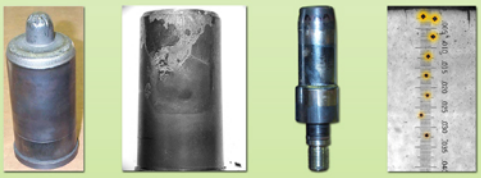
Tools, dies, and process equipment currently used in the metal casting, forging, and glass manufacturing industries are generally composed of thick-sectioned monolithic H13 or other tool steels. Although the starting materials are relatively inexpensive, the conventional tool manufacturing process results in low material yields, significant machining time, long lead times, and high overall cost. When the dies are in contact with either hot/molten metals or glass as appropriate, significant degradation of the surfaces occurs due to soldering, heat checking, and/or physical erosion. Damaged dies lead to part-surface imperfections, dimensional tolerance issues, high part-reject rate, and die repair downtime.

FORGING INDUSTRY

metaldyne GKN PLC

Problems with current industrial practices:

1. Heat Checking/Thermal Fatigue
2. Thermal Softening
3. Wear



METAL CASTING INDUSTRY

THT THT Presses, Inc.

Problems with current industrial practices:

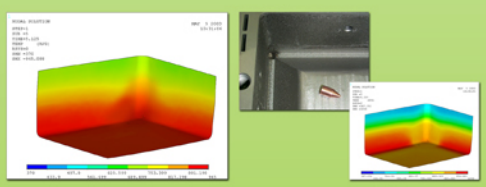
1. Heat Checking/Thermal Fatigue
2. Wear
3. Adhesion of Liquid Metal

GLASS CASTING INDUSTRY

TECHNEGLAS See Beyond the Ordinary

Problems with current industrial practices:

1. Thermal Management
2. Glass/Die Reactivity and Sticking



Technical Approach

- Identify appropriate needs for FGM metallurgical systems applicable to the metal casting, glass, and forging industries
- Thermal modeling of glass manufacturing and design of FGM glass-forming dies
- Optimization of laser powder deposition and fabricationof FGM prototype materials
- Optimization of solid-state dynamic powder consolidation and fabrication of FGM prototype materials
- Metallurgical and mechanical evaluation of materials
- Prototype trials in each of the industries

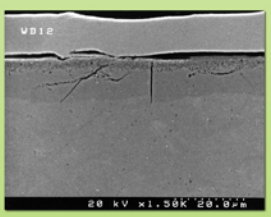
Technologies to Create Functionally Graded Materials

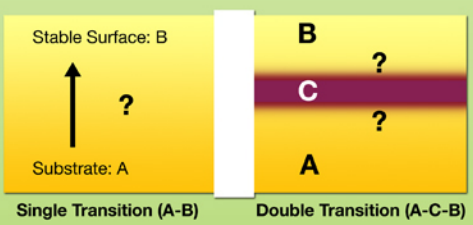
Laser Powder Deposition

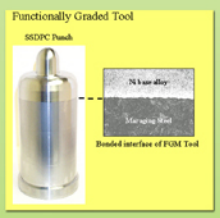
Functionally graded materials (FGMs) and structures made from ferrous or nickel-based materials and composites are candidates for this application. **Laser Powder Deposition** (LPD) and **Solid State Powder Forging** (Dynaforge) are two energy-efficient and unique near-net manufacturing processes that will be utilized in the development/ fabrication of the FGMs.

Solid State Powder Forging

New functionally graded tools and dies will enable better thermal management, possess better wear resistance, reduce scrap, and improve process productivity







Coated tools and dies can fail because of sharp material interfaces. Graded structure can provide for more robust surfaces.

Commercialization

The project includes collaboration between a leading supplier of specialty alloy metal powders and two of the largest suppliers of forged components in the world. The availability of manufacturing facilities, manufacturing process development engineers, and animmediate market for the tools will facilitate commercialization.

Partners

Carpenter Powder Products, Inc.
Bridgeville, PA

Pacific Northwest National Laboratory
Richland, WA

South Dakota School of Mines and Technology
Rapid City, SD

GKN Sinter Metals R&D
Romulus, MI

Gremada Industries, Inc.
West Fargo, ND

Metaldyne, Hatebur Operations
Royal Oak, MI

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